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TEST METHODS

CAST PLASTIC TOOLING MATERIALS

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PLASTICS TECHNICAL EVALUATION CENTER
PICATINNY ARSENAL, DOVER, N. J.

These test methods were developed for the plastics industry and its suppliers to facilitate the exchange of test data and to promote the development of materials and techniques which will advance the use of plastics in tooling applications.

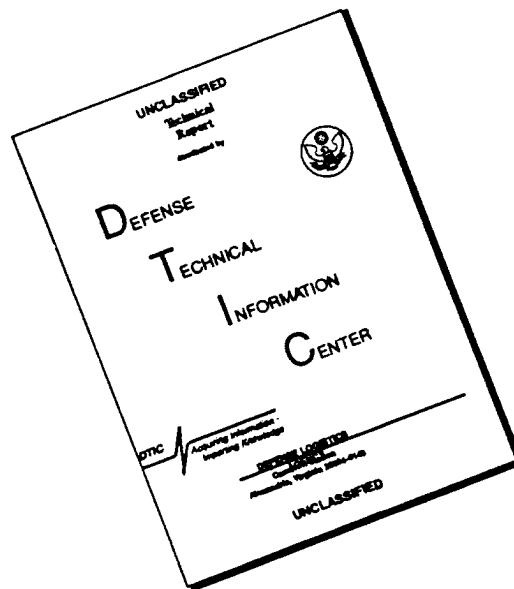
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References

SPI Test Method	References		
	ASTM Method No.	LP406b Method No.	ARTC- II Method No.
GS-1 Viscosity	-	-	-
GS-2 Gel Time	-	-	-
GS-3 Pot Life	-	-	-
GS-4 Peak Exotherm	-	-	-
GS-5 Hardness Change	D676-49T	-	-
GS-6 Shear Strength	-	-	-
GS-7 Tensile Bond Strength	D952-51	-	-
RG-1 Linear Shrinkage	-	-	-
RG-2 Coefficient of expansion	D696-44	2031	-
RG-3 Compression properties	D695-54T	1021	1
RG-4 Abrasion resistance	D1242-52T	1091	-
RG-5 Tensile Strength	D638-49T	-	2
RS-1 Hardness Change After 140°F	D676-49T	-	-
RS-2 Weathering resistance	-	-	-
RS-3 Compression set	D395-53T	-	-
RS-4 Tensile strength	D530-55T	1011	2
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CH-1 Forming oil resistance	-	-	-

SOCIETY OF THE PLASTICS INDUSTRY

TEST METHODS

CAST PLASTIC TOOLING MATERIALS

A. SCOPE AND USE

1. These test methods outline the test procedures to qualify room temperature curing materials (only) for use in the following typical tooling applications.
 - a. Facings on:
 1. Drop hammer punches.
 2. Drop hammer dies.
 3. Hydro Form blocks.
 4. Stretch Form dies.
 5. Draw dies.
 6. Draw punches and rings.
 - b. Solid castings as might be proposed.

B. EQUIPMENT

1. Brookfield Viscometer, Model MVF. Brookfield Engineering Laboratories, Stoughton, Massachusetts.
2. Shore A Scale Durometer, Shore Instrument and Manufacturing Co., Inc. Jamaica 35, New York.
3. Shore D Scale Durometer, Shore Instrument and Manufacturing Co., Inc.
4. Taber Abraser and CS-17 wheels, Taber Instruments, North Tonawanda, N.Y.
5. Inside Micrometer.
6. Randall and Stickney rubber thickness gauge. Randall & Stickney Company, Waltham, Massachusetts. (or equivalent)

C. INTRODUCTION:

1. The physical and working properties of room temperature curing tooling resin systems are affected by the factors listed below:
 - a. Temperature of materials and molds prior to casting and during curing cycle.
 - b. Total volume of the catalyzed resin mixture.
 - c. Capacity and construction of the mixing container.
 - d. Volume, construction and dimensions of the mold.
 - e. Volume and dimensions of the casting.
 - f. Age and date of resin systems.
 - g. Hardeners stored exposed to moisture.
 - h. Presence of moisture in plasters against which the tool surfaces will be made.
 - i. Types of fillers used in casting resin systems.All these may affect properties.
It is therefore imperative that these test methods be established.
2. These test methods were developed for the plastics industry and its suppliers to facilitate the exchange of test data and to promote the development of materials and techniques which will advance the use of plastics in tooling applications.

D. DEFINITIONS

1. Rigid vs. Resilient resin systems

- a. A rigid resin system shall be distinguished from a resilient resin system by the Shore D scale durometer hardness attained by the fully cured resin system. Shore hardness shall be determined in accordance with Section E.1. below. A rigid resin system shall have a Shore D scale durometer hardness of 70 or more when fully cured. A resilient resin system shall have a Shore D scale durometer hardness of less than 70 when fully cured.

2. "Fully Cured"

- a. A resin system shall be considered fully cured when the hardness of the casting does not change more than 5 points between any 60 day period during the curing cycle at 75°F, (Test GS-5). Hardness shall be determined as outlined in "General Test Procedures", section E.1. below.

E. GENERAL TEST PROCEDURES

1. Determining Shore Durometer Hardness

a. Conditioning of Specimens

- (1) When testing a resilient resin system, the specimen shall be conditioned for a minimum of 12 hours at 75 ± 2°F. prior to the hardness test.
- (2) When testing a rigid resin system, the specimen shall be conditioned for a minimum of 12 hours at 75 ± 5°F. prior to the hardness test.

b. Specimen

- (1) The specimen shall be at least 0.25 inch in thickness.
- (2) The specimen surface should be uniformly plane and preferably parallel to the opposite surface.

c. Applying Durometer to Specimen and Reading Hardness

- (1) The specimen shall rest on a hard, horizontal surface. The durometer shall be held in a vertical position and shall be applied to the test specimen while keeping the presser foot parallel to the surface of the specimen.
- (2) The instrument shall be lowered as rapidly as possible without shock. The test pressure applied shall be just sufficient to insure firm contact of the presser foot with the specimen.
- (3) The reading shall be taken and recorded (Instantaneous and 10-second dwell reading) after the instruments pressure foot has been brought into firm contact with the surface of the specimen.
- (4) In all hardness determinations, the average of ten readings shall be determined and recorded. Very low or zero readings, attained upon piercing voids in the casting, shall be disregarded.

E. GENERAL TEST PROCEDURES (Continued)1. Determining Shore Durometer Hardness (Continued)c. Applying Durometer to Specimen and Reading Hardness (Continued)

- (5) If the surface hardness of a working plastic face tool is determined in the plant, and it is impractical to stabilize this tool at $75 \pm 2^{\circ}\text{F}$., the ambient air temperature in the vicinity of the tool shall be determined within 2°F . Hardness determined in this manner shall be expressed in conjunction with the ambient air temperature as follows:

(Example:) Shore A of tool - 90/78 (82°F)

- (6) During any hardness determination tests, if the readings vary more than 10 points on either scale, the specimen shall be discarded and a new one prepared.
- (7) 0 to 95 (A scale) and 38 to 100 (D scale) shall be the effective hardness range for all rigid and resilient resin systems. Hardness values greater than 95 (A scale) or less than 38 (D scale) shall be considered invalid and shall not be reported. NOTE: A graph representing the correlation between Shore A and Shore D hardness is presented on page 33.

2. Stabilizing and Mixing Components of a Resin System

NOTE: Specify all formulae in terms of parts per Hundred parts of base resin.

- a. With the exception of control tests, Section J, all materials shall be stabilized at $75 \pm 1^{\circ}\text{F}$. immediately prior to the addition of the hardener and/or other components. In control tests, stabilize materials at $75 \pm 0.5^{\circ}\text{F}$. before test.
- b. Ambient room temperature and relative humidity shall be $75 \pm 5^{\circ}\text{F}$. and $50 \pm 20\%$ during the weighing, mixing, and casting period.
- c. The materials shall be weighed out in suitable volumetric containers in such a manner that the final volume of the mix shall be either:
 120 ± 5 Fluid ounces, or
 30 ± 2 Fluid ounces
 as called for in the applicable procedures below.
- d. The mixing container shall be of thin gauge metal construction, such as a commercial paint container.
- e. If three or more components are involved in the resin system, the hardener or catalyst shall be added last, unless otherwise recommended by the manufacturer. After the addition of each component to the base resin, the mixture shall be blended manually with a suitable stirring bar. If any one of the components has a viscosity over 10,000 cps., the mixture shall be blended for five minutes. If none of the individual components has a viscosity over 10,000 cps., blending of the mixture shall be for three minutes. This would apply to both gallon or quart quantities. Care shall be taken to assure that the bottom, sides, and center of the mass all receive approximately the same amount of blending agitation.
- f. Zero time for measurement of Gel Time and Pot Life shall be at the point that the mixing period has been completed.

E. GENERAL TEST PROCEDURES (Continued)

3. Temperature Control During Curing and Testing of Specimens

- a. Unless otherwise specified, all cast specimens shall be cured and tested at $75 \pm 5^{\circ}\text{F}$ and $50 \pm 20\%$ relative humidity.

4. Curing Time Periods Before Tests

- a. Unless otherwise specified, all specimens for determination of physical properties shall be tested immediately after the following respective curing time periods:

- (1) 72 ± 5 hours
- (2) 30 days
- (3) 6 (six) months

- b. The age of the specimen shall be reported in conjunction with all test results.

5. Identification and Proportions of Components in a Resin System

- a. The batch number, date of manufacture, and exact weight ratio expressed as parts per 100 parts of resin of each component in the resin system shall be recorded and expressed in conjunction with the results of all tests.

6. Number of Tests Required

- a. Unless otherwise specified, a minimum of three specimens shall be prepared and tested for each individual condition.

7. Loading Rate

- a. Unless otherwise specified, the rate of loading specimens in the test machine shall be uniform and adjusted so as to require an elapsed time of two to three minutes from initial loading to ultimate failure of the specimen.

8. Flow Charts Outlining Sequence of Specimen Fabrication and Testing

- a. The flow charts outlining the sequence of specimen fabrication and testing are presented on pages 30, 31, and 32.

F. GENERAL SCREENING TESTS - ALL RIGID AND RESILIENT RESIN SYSTEMS

GS-1 Casting Viscosity

- a. A total of 120 ± 5 fluid ounces shall be blended in accordance with the mixing procedure outlined in E.2. above.
- b. Immediately after all components have been thoroughly blended, the viscosity shall be determined within the following two minute period.

F. GENERAL SCREENING TESTS - ALL RIGID AND RESILIENT RESIN SYSTEMS (Continued)GS-1 Casting Viscosity (Continued)

- c. The Brookfield viscometer shall be used in all viscosity determinations.
- d. Viscosity shall be expressed in centipoises (cps.) as: "Casting viscosity, stabilized at $75 \pm 1^{\circ}\text{F.}$ "

GS-2 Gel Time on Kirksitea. For rigid resin systems

- (1) A 1/2" thick Kirksite (~~60~~ surface finish) sheet shall be coated with a suitable parting agent. The dimensions of the sheet and damming shall be such as to result in a $3/8 \pm 1/32$ " thick plastic casting 17" x 17".
- (2) Immediately after the viscosity test, 60 fluid ounces shall be cast onto the Kirksite sheet. The top surface of the casting shall be exposed to the ambient air.
- (3) Gel time shall be considered as that time period at which the blended resin at the center of the mass is no longer fluid to the moderate scooping action of a tongue depressor, or other suitable instrument.

b. For resilient resin systems

- (1) The dimensions and preparation of the 1/2" thick Kirksite (~~60~~ surface finish) sheet shall be such so as to result in a plastic casting $3/8 \pm 1/32$ " X 15" X 17" half of which is bonded and half unbonded to the Kirksite.
- (2) The surface of the area which will encompass the unbonded portion of the casting shall be coated with a suitable parting agent. No parting agent shall be applied to the area in which the plastic will be bonded.
- (3) The surface of the area which will encompass the bonded portion shall be sand-blasted with beach sand, Flintbrasive #1, #50 aluminum oxide, or any other equivalent.
- (4) Immediately after the viscosity test, 54 fluid ounces shall be cast onto the Kirksite sheet. The top surface of the plastic casting shall be exposed to the ambient air.
- (5) Gel time shall be considered as that time period from zero time (when mixing is completed) to the point at which the blended resin is no longer fluid to the moderate scooping action of a tongue depressor, or other suitable instrument.

GS-3 Pot Life 3-3/8" Thick Mass in 1 Gallon Metal Container

- a. The remaining 60 fluid ounces shall be used for the Pot Life determination. Pot Life shall be considered as that time period from zero time (when mixing is completed) to the point at which the blended resin is no longer fluid to the moderate scooping action of a tongue depressor, or other suitable instrument.

F. GENERAL SCREENING TESTS - ALL RIGID AND RESILIENT RESIN SYSTEMS (Continued)GS-4 Peak Exotherm

- a. Peak exothermic temperature and the time required to reach peak exothermic heat shall be determined by means of a thermocouple lead wire inserted at the center of the mass in the pot life and gel time specimens, respectively. Temperature shall be determined by any suitable instrument, accurate to within 3°F. Zero time shall be that point at which mixing of the resin system is completed.

GS-5 Hardness Change During Curing Period at 75°F.a. Specimen(1) Rigid resins

- (a) Specimen for hardness test shall be a 6" x 6" portion of the gel time specimen, Test GS-2.

(2) Resilient resins

- (a) Specimen for hardness test shall be a 6" x 6" bonded portion of the gel time specimen, Test GS-2.
- (b) Specimen shall be cured and tested at $75 \pm 2^\circ\text{F}$.

- b. The Shore durometer shall be used to determine hardness in accordance with E.1. above.

- c. The hardness of the specimen shall be determined at the following time intervals of curing:

1. 24 hours
2. 72 hours
3. 1 week
4. 30 days
5. 6 months

- d. A curve shall be plotted with the change in Shore hardness as the ordinate and curing time as the abscissa.

GS-6 Shear Strength When Bonded to KirksiteMethod 1 - Block Sheara. Specimen

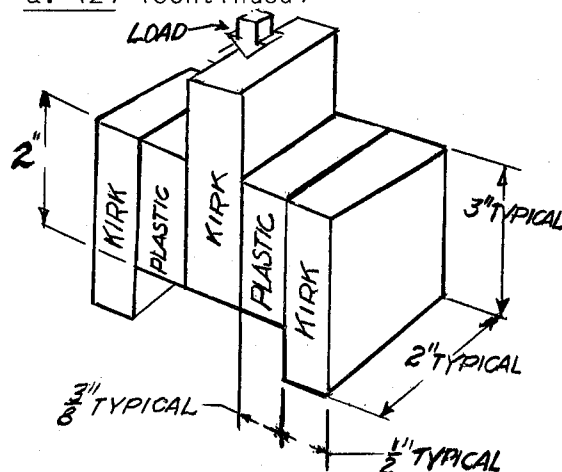
- (1) The bonding surfaces of the Kirksite blocks shall be free from oils, grease, contaminants, finger prints, etc., after abrasive blasted with #50 aluminum oxide, beach sand, Flintbrasive #1, or any other equivalent material.
- (2) The plastic shall be cast from the mix totaling 30 fluid ounces as outlined on page 3, Section E.2. The bonded blocks shall be spaced and mounted in accordance with the following sketch:

F. GENERAL SCREENING TESTS - ALL RIGID AND RESILIENT RESIN SYSTEMS (continued)

GS-6 Shear Strength When Bonded to Kirksite (continued)

Method 1 - Block Shear (continued)

a. (2) (Continued)



AREA OF PLASTIC IN CONTACT
WITH KIRKSITE SHALL BE
4 SQUARE INCHES

(3) Seal and pour while on side; center block should be parallel to and centered between side blocks within .005". Upper and lower surfaces should be parallel within .003".

(4) Kirksite sheets procured for these tests shall be cast in a closed mold, with a pour gate and vent, to produce minimum porosity.

b. Strain measurement

(1) A suitable instrument shall be attached to the cross heads of the testing machine and shall be capable of indicating the increase in specimen length (2") within an accuracy of .001".

c. Reporting results

(1) The ultimate shear strength shall be the stress at rupture and shall be calculated from the formula:

$$\text{Ultimate shear strength (psi)} = \frac{\text{total load (lbs)}}{4 \text{ (bonded area)} \times 2}$$

(2) Shear strain shall be a function of the shear stress at any given time and shall be calculated by the formula:

$$\text{Shear strain (inches/inch)} = \frac{\Delta}{T}$$

where:

Shear strain = the strain in inches/ inch of specimen length.

Δ = increase in specimen length.

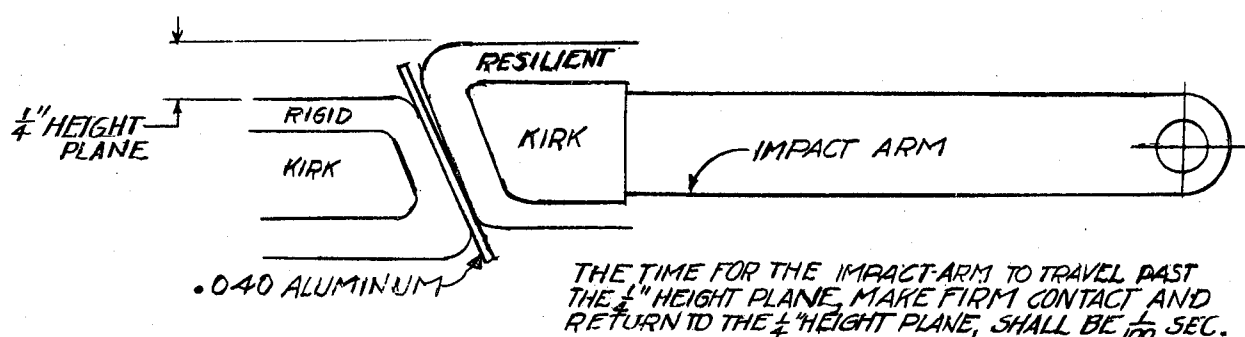
T = original thickness of plastic specimen

F. GENERAL SCREENING TESTS - ALL RIGID AND RESILIENT RESIN SYSTEMS (continued)GS-6 Shear Strength When Bonded to Kirksite (continued)Method 1 - Block Shear (continued)c. Reporting results (continued)

- (3) A curve shall be plotted with shear stress, expressed in psi, as the ordinate and shear strain, expressed in inches per inch, as the abscissa.

Method 2 - Shear impact resistance

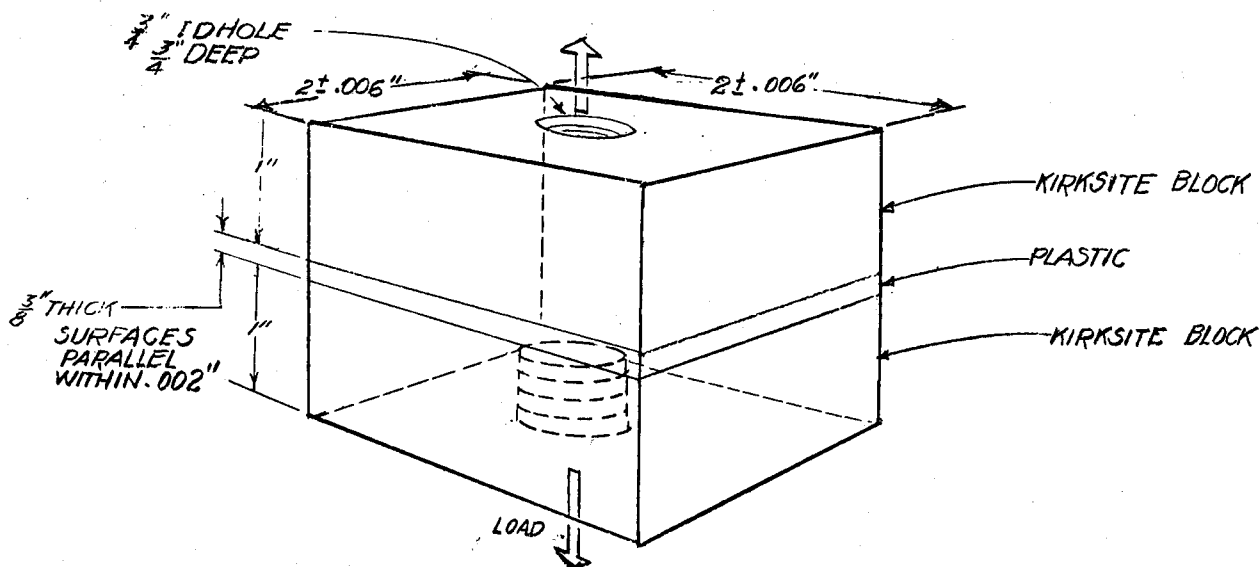
- a. Test is performed in accordance with the following sketch:



- b. (Configurations and calculations are currently under evaluation.)

GS-7 Tensile Bond Strength to Kirksite

- a. Specimens shall be prepared in accordance with the following sketch:

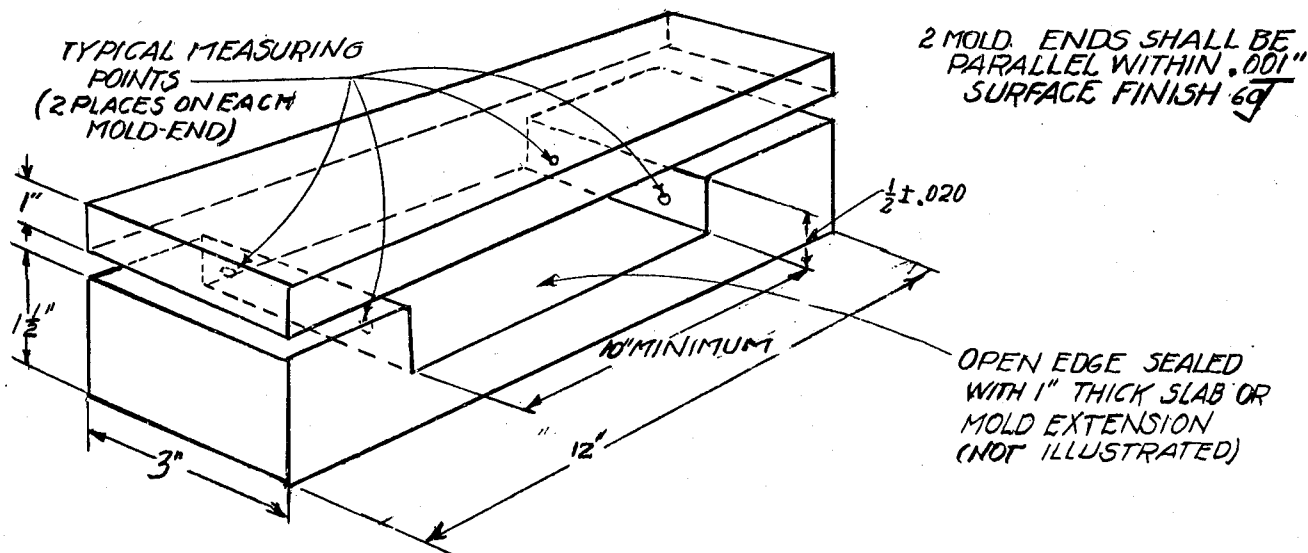


F. GENERAL SCREENING TESTS - ALL RIGID AND RESILIENT RESIN SYSTEMS (continued)GS-7 Tensile Bond Strength to Kirksite (continued)

- b. Specimens shall be cast from the mix totaling 30 fluid ounces as outlined on page 4, Section E.2.
- c. Kirksite sheets procured for these tests shall be cast in a closed mold, with a pour gate and vent, to produce minimum porosity.
- d. Bonding surfaces of the test blocks shall be abrasive blast cleaned with aluminum oxide #50, beach sand, Flintbrasive #1, or any other equivalent material.
- e. Tensile bond strength shall be reported only in the case of 100% adhesive failure of the plastic being tested, i.e. at the plastic to metal bond line. If failure occurs within the metal block surface or within the plastic, this failure shall be noted and recorded and the bondstrength reported as a value greater than the actual value attained in the test.
- f. Care shall be exercised to prevent any notch or scratch introduction into the exposed edges of the plastic before test. A deep scratch in the plastic surface can introduce a notch effect and cause premature failure.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMSRG-1 Linear Shrinkage During CureMethod 1 - Flat Bar (Cast in both plaster and Kirksite molds)a. Mold

- (1) Plaster or Kirksite mold walls shall be 1" thick. The 2 ends used for measuring length of the mold cavity shall be parallel to within .001" over the 3" width. The surface finish of the two mold ends shall be $60\sqrt{}$. In the case of plaster molds, the surface finish of the metal pattern ends, from which the mold shall be cast, shall be $60\sqrt{}$.



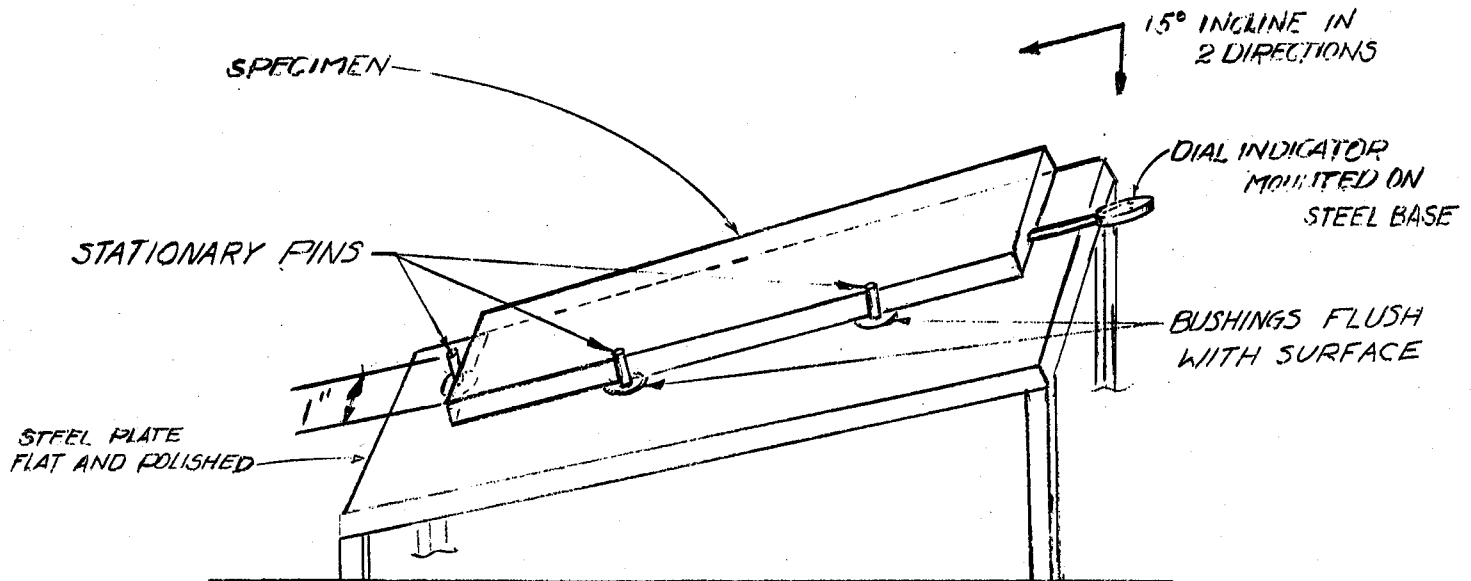
G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)RG-1 Linear Shrinkage During Cure (Method 1-Flat Bar)(Continued)a. Mold (Continued)

- (2) Mold shall be fabricated in such a manner as to result in a cast specimen $\frac{1}{2} \pm .020$ " thick x 3" x 10" (Minimum)
- (3) After application of suitable parting agents, the mold and measuring apparatus shall be stabilized at $75 \pm 2^{\circ}\text{F}$. The 10" inside dimension of the mold shall be measured at a minimum of two points with an inside micrometer accurate to within .001". The pressure foot of each end of the micrometer shall be a minimum of $\frac{1}{4}$ " diameter. Care shall be exerted to insure that the two ends of the micrometer are perpendicular to the mold ends during the measurement.

b. Specimen preparation and measurement

- (1) Specimen shall be cast from the mix totaling 30 fluid ounces as outlined on page 3 Section E.2.
- (2) The specimen shall be allowed to cure at $75 \pm 2^{\circ}\text{F}$ for 24 hours.
- (3) The specimen shall then be released from the mold, inserted into the fixture illustrated below, and length measured between a stationery point and a dial indicator. The span between the stationery point and the dial indicator shall have previously been calibrated to the inside micrometer. The second measurement shall be attained by inverting the specimen.

NOTE: In the case of resilient formulations a $\frac{1}{16}$ " flat metal plate shall be bonded to or positioned against the edges of the specimen, i.e. the edges nesting against the stationery pins & dial indicator foot.



* Thickness of $\frac{1}{2}$ " is proposed, although other specimen thicknesses are acceptable but must be reported in test results.

G. RG-1 Linear Shrinkage During Cure (Method 1 - Flat Bar) (Continued)b. Specimen preparation and measurement (continued)

- (4) The dial indicator and stationery pin shall be in a plane parallel to the plane of the 2 removable pins. The average of two length measurements shall be determined of each specimen.
- (5) All specimens and measuring apparatus shall be stabilized at $75 \pm 2^{\circ}\text{F}$. immediately prior to each measurement during the curing period.
- (6) Measurements shall be taken after each of the following curing periods:

Cure A

- (a) 24 hours at $75 \pm 2^{\circ}\text{F}$.
- (b) 72 hours at $75 \pm 2^{\circ}\text{F}$.
- (c) 30 days at $75 \pm 2^{\circ}\text{F}$.
- (d) 6 months at $75 \pm 2^{\circ}\text{F}$.

Cure B

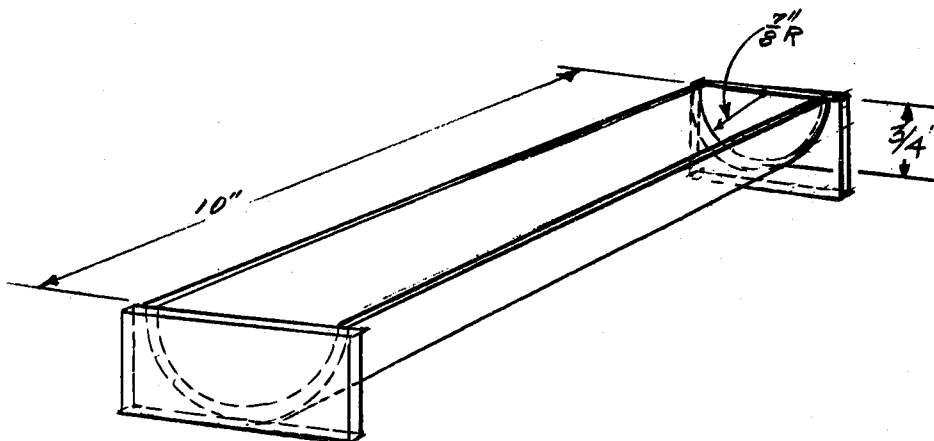
- (a) 24 hours at $75 \pm 2^{\circ}\text{F}$.
- (b) 6 days at $75 \pm 2^{\circ}\text{F}$.
- (c) 6 days at 140°F + 24 hours at $75 \pm 2^{\circ}\text{F}$.

c. Reporting results

- (1) Shrinkage shall be expressed in inches per inch of specimen length. Type of mold (all plaster or all Kirksite) and age of specimen shall be specified when reporting results.

Method 2 - Half-Round Rod (Cast in plaster or nickel-plated steel molds)a. Mold

- (1) A polished nickel-plated steel mold shall have walls $5/16"$ thick. A plaster mold shall have a $1"$ wall thickness. The ends used for measuring the length of the mold cavity shall be parallel to within $0.0005"$.



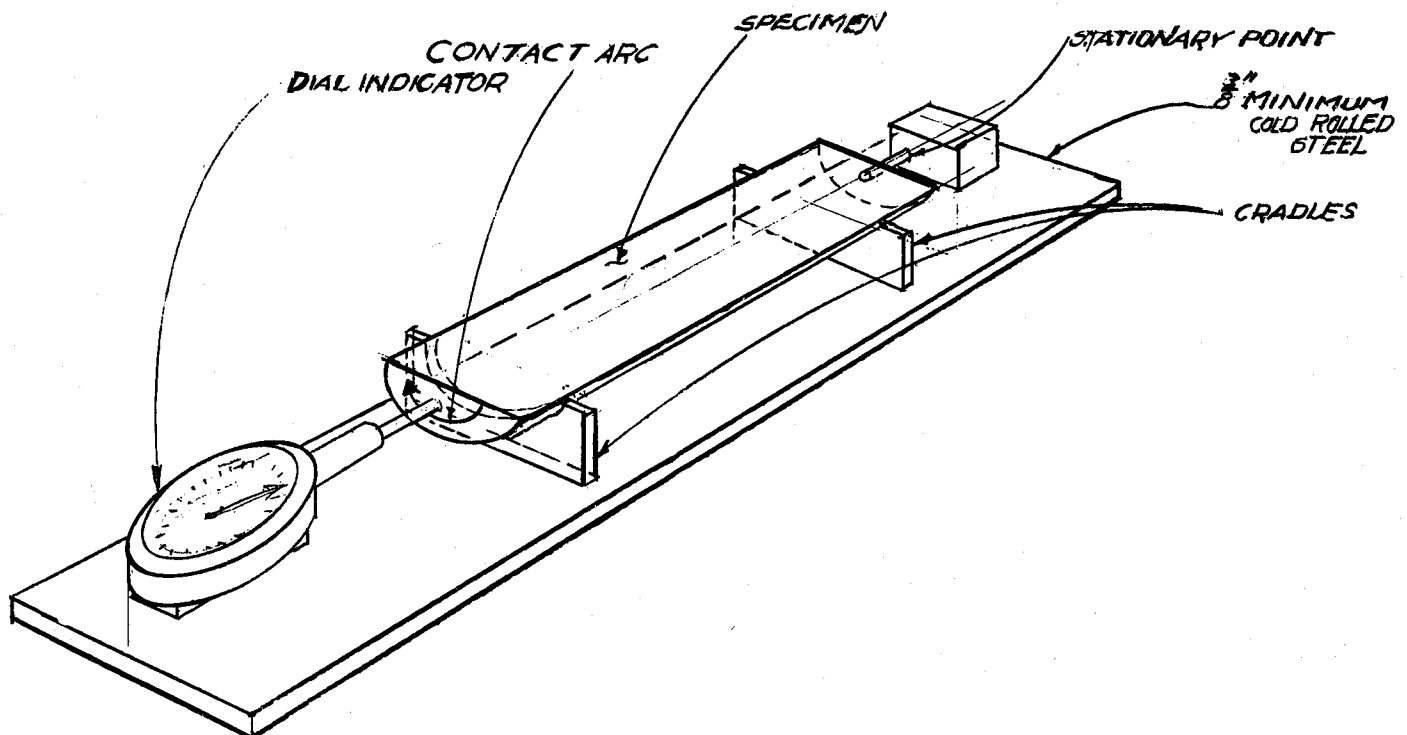
- (2) Mold shall be fabricated in such a manner as to result in a cast specimen $3/4" \times 1-3/4" \times 10"$. The specimen shall be in a half-round shape with one surface on a $7/8"$ radius.

G. RG-1 Linear Shrinkage During Cure (Method 2 - Half Round Rod) (Continued)a. Mold (Continued)

- (3) After application of suitable parting agents, the mold and measuring apparatus shall be stabilized at $75 \pm 2^\circ\text{F}$. The 10" inside dimension of the mold shall be measured with an inside micrometer accurate to within .001". Care shall be exerted to insure that the two ends of the micrometer are perpendicular to the mold ends during the measurement.

b. Specimen Preparation and Measurement

- (1) Specimen shall be cast from a mix totaling 30 fluid ounces as outlined in E-2.
- (2) The specimen shall be allowed to cure at $75 \pm 2^\circ\text{F}$ for 24 hours.
- (3) The specimen shall then be released from the mold, inserted into the fixture illustrated below, and the length measured between the stationary point and the dial indicator. The span between the stationary point and the dial indicator shall have previously been calibrated to the inside micrometer.



G. RG-1 Linear Shrinkage During Cure (Method 2 - Half Round Rod) (Continued)b. Specimen Preparation and Measurement (Continued)

- (4) The 2 cradles shall hold the specimen so that the stationary point and the contact point of the dial indicator are at a perpendicular to the ends. The dial indicator point and stationary point must contact the specimen at a point 1/2" from the curved surface. Thus, the specimen is rotated and the points will form an arc of contact on the end of the specimen. The average reading as the specimen is rotated shall be determined for each specimen.
- (5) All specimens and measuring apparatus shall be stabilized at $75 \pm 2^{\circ}\text{F}$. immediately prior to each measurement.
- (6) Measurements shall be taken after each of the following curing periods:

Method A

- (a) 24 hrs. at $75 \pm 2^{\circ}\text{F}$.
- (b) 72 hrs. at $75 \pm 2^{\circ}\text{F}$.
- (c) 30 days at $75 \pm 2^{\circ}\text{F}$.
- (d) 6 months at $75 \pm 2^{\circ}\text{F}$.

Method B

- (a) 24 hrs. at $75 \pm 2^{\circ}\text{F}$.
- (b) 6 days at $75 \pm 2^{\circ}\text{F}$.
- (c) 6 days at 140°F plus
24 hours at $75 \pm 2^{\circ}\text{F}$.

c. Reporting Results

- (1) Shrinkage shall be expressed in inches per inch of specimen length. Type of mold (steel or plaster) and age of specimen shall be specified when reporting.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)RG-2 Coefficient of Linear Thermal Expansion, +40 to +140°Fa. Scope

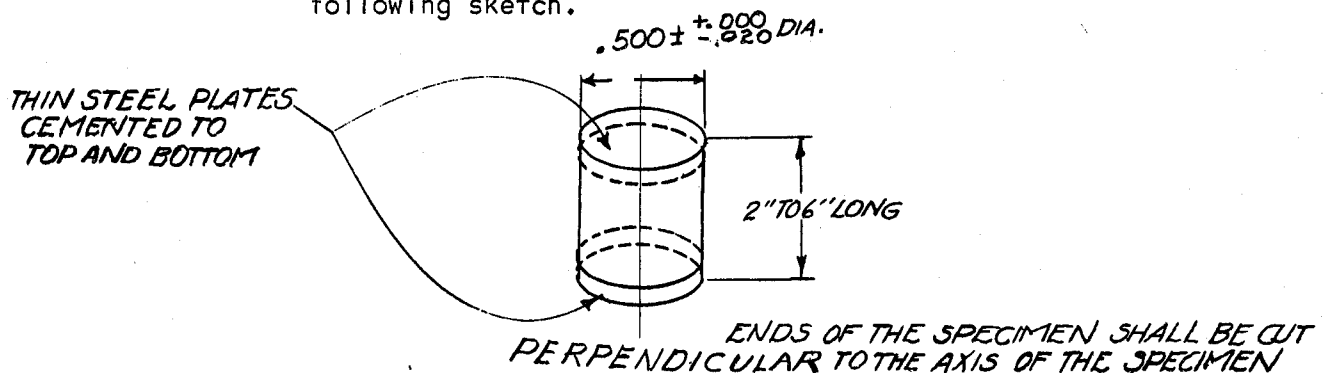
- (1) This method outlines the procedure for determining the true expansion coefficient of a cast plastic after the plastic has completely polymerized.

b. Mold

- (1) Mold shall be a metal tube with a wall thickness of 1/32" and an inside diameter of 1/2".
- (2) A groove shall be cut in the outside wall of the tube in the longitudinal direction with a hack saw or band-saw to facilitate re-moval of the specimen.
- (3) A suitable parting agent shall be applied to the inside surface of the tube.
- (4) After the plastic is cast, the outside surface of the metal tube shall be exposed to ambient air ($75 \pm 5^\circ\text{F.}$) for 24 hours.

c. Specimen

- (1) Specimen shall be cast from the mix totaling 30 fluid ounces as outlined on page 3 Section E.2.
- (2) The dimensions of the specimen shall be in accordance with the following sketch.



G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)

RG-2 Coefficient of Linear Thermal Expansion, +40 to +140°F. (Continued)

d. Conditioning the specimen

Cure A

- (1) Specimen shall be tested after it has reached the fully cured state as outlined in Section D, "Definitions".

Cure B

- (1) Specimen shall be tested after it has been cured for 7 days at $75 \pm 5^\circ\text{F.}$ and six days at 140°F.

e. Quartz tube dilatometer

Outer Tube. - An outer tube of fused quartz 20 in. in length, 1/2 in. in inside diameter, and about 2mm. in wall thickness. The tube is sealed on the lower end, the sealing surface being convex on the inside to provide one-point contact with the thin steel plate cemented to the lower end of the specimen.

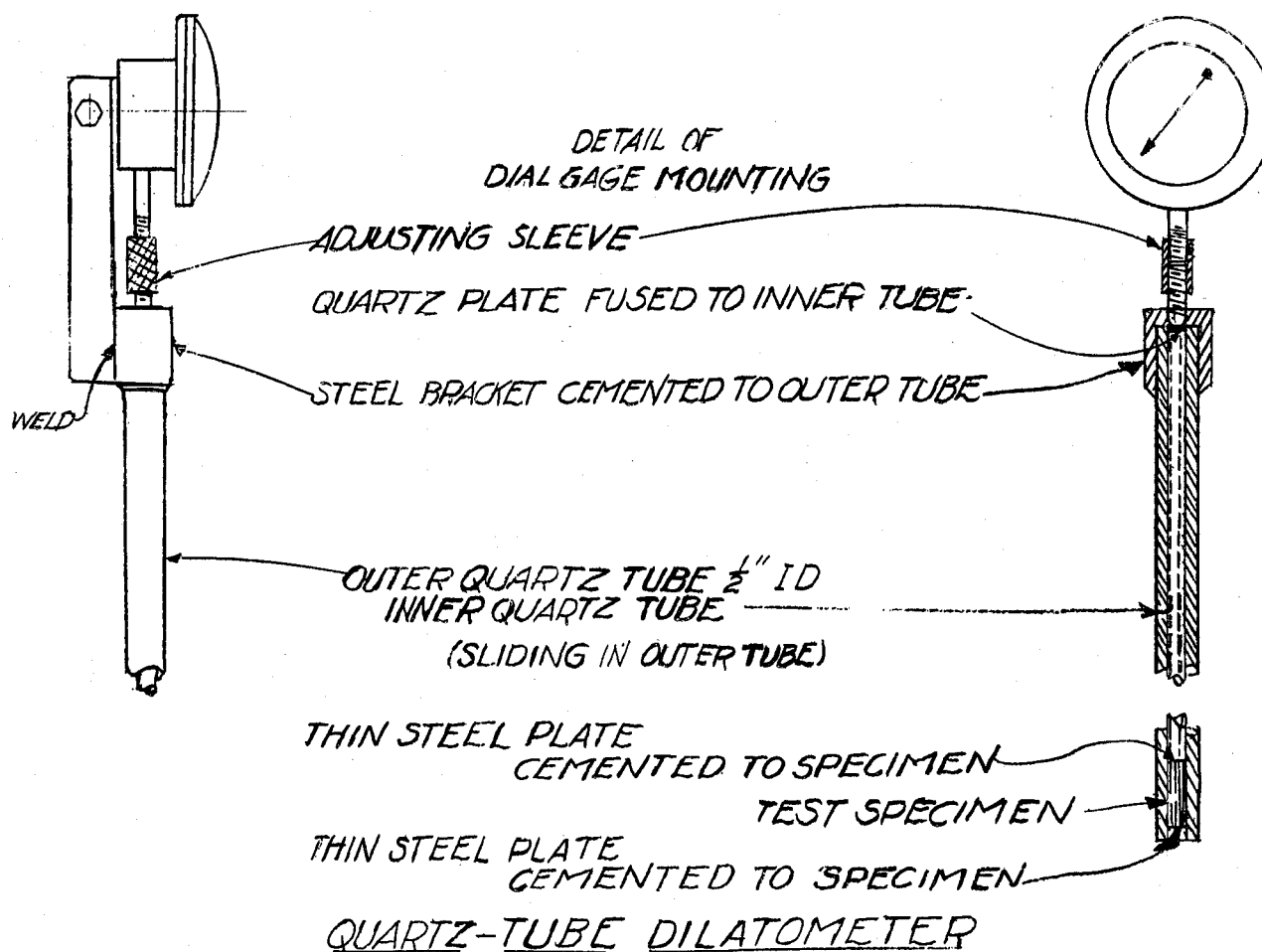
Inner Tube. - An inner tube of fused quartz 16 to 18 in. in length with an outside diameter that allows this tube to fit snugly inside the outer tube without binding. The length of the inner tube is determined by the length of the specimen, since the upper ends of the inner and outer tubes should be at the same level when the specimen is in place. One end of the inner tube is closed with a hemispherical seal to provide one-point contact with the thin steel plate cemented to the upper end of the specimen. To the end of the inner tube is attached a thin steel plate or is fused a quartz plate which serves as a rest for the foot of the dial gage. The wall thickness of the inside quartz tube should be as small as practical in order to reduce the load on the specimen.

Dial Gage. - A dial gage mounted on a bracket which is securely fastened to the upper end of the outer tube. The dial gage is preferably calibrated to 0.0001 in. per division. The stem of the dial gage should be concentric with the quartz tube.

Mounting. - The dilatometer is mounted vertically on a solid support in such a way that the temperature bath can readily be changed without disturbing the dilatometer.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)

RG-2 Coefficient of Linear Thermal Expansion, +40 to +140°F. (Continued)

f. Procedure

- (1) The length of the specimen shall be measured at room temperature with a suitable instrument with an accuracy of $\pm 0.5\%$.
- (2) A liquid bath shall be arranged in such a way that uniform temperature throughout the specimen is assured. Means shall be provided for stirring the bath and for controlling its temperature within plus or minus 0.5°F at 40°F and at 140°F .
- (3) The conditioned specimen shall be mounted in the dilatometer. The temperature of the bath shall be maintained at $+40 \pm 5^{\circ}\text{F}$. until the temperature of the specimen reaches the temperature of the bath. The time required shall be pre-determined on a blank specimen with an embedded thermocouple. The reading of the dial indicator that indicates the dimensional change of the specimen shall be recorded.
- (4) With the temperature at $140 \pm .5^{\circ}\text{F}$, the procedure in paragraph (3) above shall be repeated.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)RG-2 Coefficient of Linear Thermal Expansion, +40 to +140°F. (Continued)g. Calculations and reporting results

- (1) The expansion coefficient shall be calculated over the 40 to 140°F temperature range by the following formula:

$$\alpha = \frac{\Delta L}{L \times T}$$

where α = coefficient of linear thermal expansion expressed as $\alpha \times 10^{-5}$ inch/inch/°F, 40°F to 140°F

ΔL = Average of changes in length of test specimen due to heating and cooling

L = Length of test specimen at room temperature (ΔL and L being measured in the same units.)

T = Temperature difference in degrees fahrenheit (100°F)

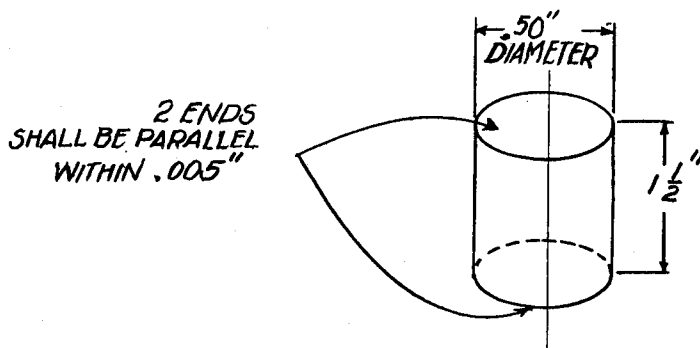
- (2) Cure period (A or B) shall be reported.

G. RG-3 Compression Properties (Rupture Stress, Deformation, Fatigue, and Creep)a. Scope

This method outlines the procedure for determining the compressive rupture stress, 0.2% offset yield stress, a stress-strain curve, elastic modulus, fatigue, deformation, and creep that occurs under compressive loads.

b. Specimen preparation

- (1) Specimens shall be cast from the mix totaling 30 fluid ounces as outlined on page 3 Section E.2.
- (2) Specimens shall be cast in a thin (approximately 1/32" wall) metal tube 1/2" I.D. with the outside surface of the tube exposed to the ambient air.



SPECIMEN FOR COMPRESSION TESTS

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)

RG-3 Compression Properties (Rupture Stress, Deformation, Fatigue, and Creep)(Con't)

c. Strain measurement

- (1) A suitable instrument shall be attached to the cross-heads of the testing machine and shall be capable of indicating the change in specimen length within an accuracy of .001". The strain measurement shall be a function of the compressive stress at any given time and shall be expressed as a percentage of the original specimen length.

d. Compressive strength test

- (1) Compressive rupture stress shall be the stress per unit area, expressed in psi, at which ultimate failure occurs.
- (2) A stress strain curve shall be plotted with stress, expressed in psi as the ordinate, and strain, expressed as a percentage of the original specimen length, as the abscissa.
- (3) The percentage compressive strain shall be expressed as the percentage strain for any given load in compression.
- (4) 0.2% offset yield stress shall be the stress, expressed in psi, at which the stress-strain curve departs from linearity by 0.2% strain.
- (5) Elastic modulus (E), the ratio within the elastic limit of the nominal compressive stress to the corresponding compressive strain, shall be expressed in psi. E shall be calculated by dividing the 0.2% offset yield stress by the corresponding strain.

e. Compressive fatigue at various loads

- (1) A compressive load shall be applied to the specimen from zero to maximum and returned to zero at a rate of 12 cycles per minute. This shall be repeated until the specimen has failed.
- (2) The number of cycles to produce failure shall be recorded and expressed as the number of cycles at the desired load (psi) to produce compressive fatigue failure.

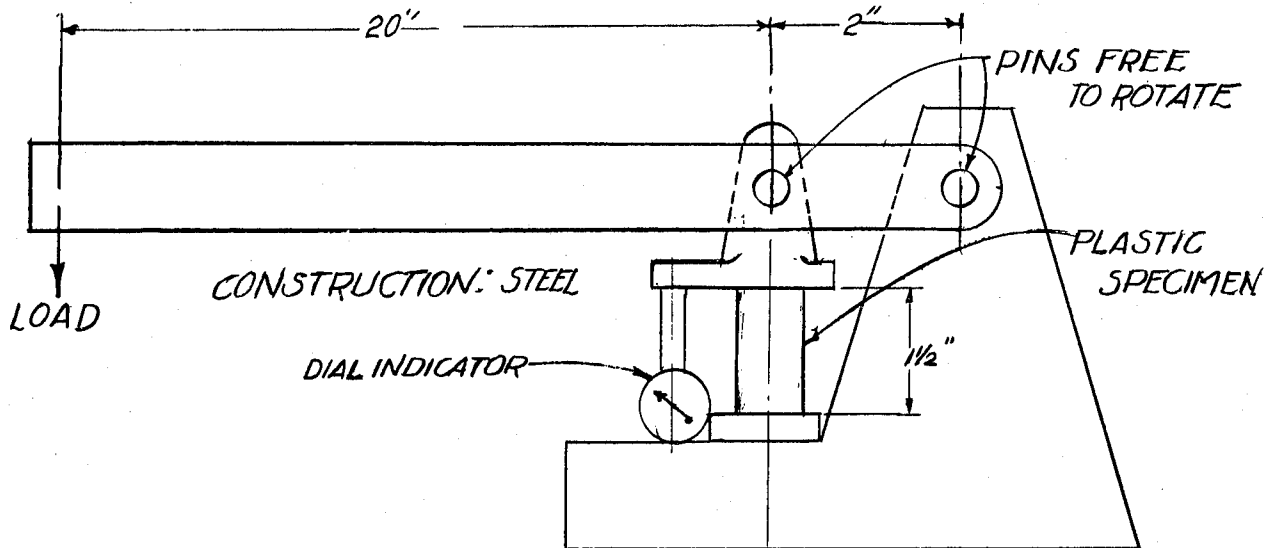
f. Compressive deformation

- (1) The permanent deformation incurred in the compressive fatigue specimens shall be recorded after the tenth cycle and after every 1000th cycle. Compressive deformation shall be expressed as % of original length.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)

RG-3 Compression Properties (Rupture Stress, Deformation, Fatigue, and Creep) (Cont'd)

g. Compressive creep



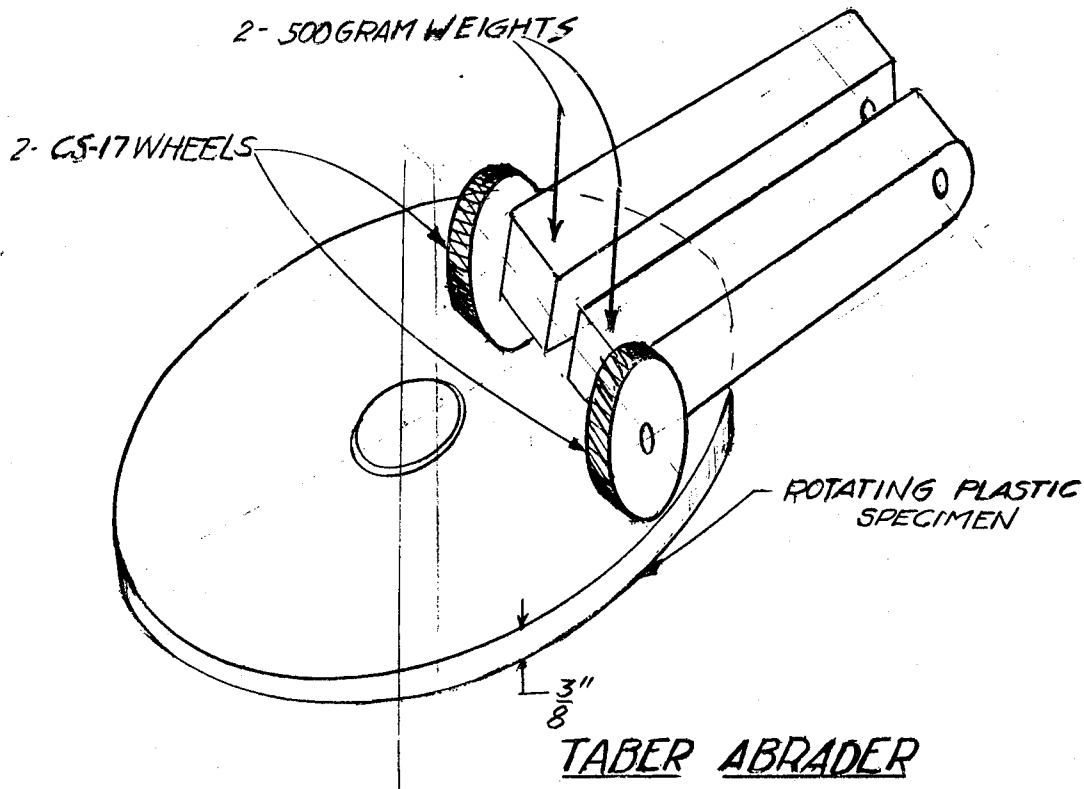
CREEP FIXTURE

- (1) A constant compressive load shall be applied. The load shall be 50% of the ultimate compressive strength of the material.
- (2) Initial strain, final strain, and % recovery (after removal of load) shall be recorded and expressed in conjunction with the time period and temperature of the test.

G. RG-4 Abrasion Resistance

Abrasive Wheel on Flat Specimen

- a. Specimen shall be a portion of the Gel time specimen, Test GS-2, and shall be tested in the Taber Abraser. The specimen surface adjacent to the Kirksite shall be exposed to the abrasive wheels during the test. Taber CS-17 wheels shall be equipped with a 500 gram external load and mounted so that the total weight of the wheel and 500 gram load shall be exerted on the specimen during the abrasion test.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)RG-4 Abrasion Resistance (Continued)

- b. 5000 cycles shall be conducted and the abrasion shall be expressed both as volume loss and thickness loss. Wheels are to be refaced after every 1000 cycles.
- c. The volume loss, for 5000 cycles, shall be calculated as follows:

$$\text{Volume loss, cu.cm.} = \frac{W_1 - W_2}{S}$$

Where W_1 = Initial weight of specimen in grams

W_2 = weight after abrasion, in grams

S = specific gravity of material being abraded

Weight shall be determined on a suitable analytical balance, accurate to within .001 grams.

- d. Thickness loss shall be determined with a micrometer before and after abrasion and reported.
- e. Both weight loss and thickness loss shall be reported.

a. Specimen

Technical drawing of a mechanical part with the following dimensions and features:

- GAGE MARKS:** Indicated by arrows pointing to the top and bottom surfaces of the central section.
- Top Surface Dimensions:**
 - Radius: $R = \frac{9}{16}$ "
 - Distance from the left edge to the start of the radius: $.500 \pm .005$ "
- Bottom Surface Dimensions:**
 - Distance from the left edge to the start of the radius: $2\frac{5}{16}$ "
 - Distance between the two radii: 1 "
- Overall Dimensions:**
 - Total length: $5\frac{1}{2}$ "
 - Distance from the right edge of the central section to the right edge of the part: 1 "
 - Distance from the right edge of the part to the center of the hole: $.375 \pm .005$ "
- Other Features:**
 - A hole with a diameter of 1 " is located on the right side of the part.
 - The part has a central section with a width of 1 " and a total width of 1 " on the right side.

TENSILE TEST SPECIMEN

Tensile strength shall be determined on a power-driven apparatus of either the beam-weighing or pendulum type conforming to the following requirements:

The indicator shall remain at the point of maximum load after rupture of the test specimen.

Type of extensometer used in measuring elongation of the test specimen shall be reported in results; it should be capable of $\pm .001$ " reading.

The testing machine used for a given test machine shall be of such capacity that the maximum load required to break the specimen shall not exceed 85 per cent nor be less than 15 per cent of this rated capacity.

The grips which hold the specimen in the testing machine may be of a wedge type which tighten automatically and exert a uniform pressure across the gripping surface proportional to the applied tension, or of the type which may be tightened by screw pressure by hand. The gripping surfaces shall be knurled to prevent slippage of the test specimen.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)

RG-5 Tensile Strength (Continued)

d. Reporting Results

- (1) Ultimate tensile strength, expressed in psi, shall be calculated by dividing the maximum load in pounds by the original area of cross-section of the test specimen in square inches and shall be expressed in psi.
- (2) Representative stress - strain curve shall be plotted with stress, in pounds per square inch, as ordinate and corresponding strain, as elongation per unit gage length, as abscissa for the entire course of the tensile test at temperature condition.

G. SPECIFIC SCREENING TESTS FOR RIGID RESIN SYSTEMS (Continued)RG-5 Tensile Strength (Continued)e. Definitions

- (1) Stress - Stress is defined as a tensile load per unit area and is determined from the formula:

$$S = \frac{P}{A}$$

Where

S = Tensile stress, in pounds per square inch
 P = Total Tensile load in specimen, in pounds
 A = Initial cross-sectional area in the gage length of the specimen, in square inches.

- (2) Rupture Stress - is the ultimate tensile strength and is defined as the stress, in pounds per square inch on the specimen at rupture.
- (3) Strain - Strain is defined as elongation of specimen per unit gage length in inches or unity.

H. SPECIFIC SCREENING TESTS FOR RESILIENT RESIN SYSTEMSRS-1 Hardness Change When Exposed to 140°F

- a. Specimen shall be a 6" X 6" bonded portion of the Gel Time Specimen, Test GS-2.
- b. The specimen shall be exposed to accelerated aging cycles after curing 24 hours at $75 \pm 2^\circ\text{F}$.
- c. One accelerated aging cycle shall consist of
- (1) 24 hours at 140°F .
 - (2) 24 hours at $75 \pm 2^\circ\text{F}$.
- d. Shore hardness shall be determined at the end of each 24 hour period at $75 \pm 2^\circ\text{F}$.

H. SPECIFIC SCREENING TESTS FOR RESILIENT RESIN SYSTEMS (Continued)RS-1 Hardness Change When Exposed to 140°F (Continued)

- e. Cycling shall continue until that point at which there is no change in hardness or for fifteen cycles, whichever is sooner.
- f. A curve shall be plotted indicating the change in hardness when the specimen is exposed to accelerated aging cycles.

RS-2 Weathering Resistance

- a. Specimen shall be a 4" x 6" bonded portion of the Gel time specimen, Test GS-2. The specimen shall have aged 24 hours before test.
- b. The Shore hardness shall be determined in accordance with E.I. above.
- c. The specimen shall be exposed to 140°F and 95% relative humidity for 7 days.
- d. Any change in the surface or appearance of the specimen shall be reported.
- e. The change in hardness, when measured in accordance with E.I. above, shall be reported.

RS-3 Compression Seta. Scope

This method outlines the procedure for determining the change in thickness of a 3/8" thick specimen subjected to a static compressive load for a specified time period at a specified temperature.

b. Specimen

- (1) Specimen source shall be an unbonded portion of the Gel time specimen, Test GS-2. The specimen shall be a disk cut to a diameter of 1.129" and the thickness shall be $375^{+}.005^{+}.020$ ".
- (2) The specimen shall have aged for 24 hours immediately prior to the test.
- (3) The original and final average thickness shall be measured with a standard dial rubber micrometer (Randall and Stickney thickness gauge, or equivalent) to the nearest .001".

c. Loading device

- (1) A static load (lead weights) or a calibrated spring load shall be arranged so as to exert the required loads. The specimen shall be placed between flat steel plates.

H. SPECIFIC SCREENING TESTS FOR RESILIENT SYSTEMS (Continued)RS-3 Compression Set (Continued)d. Procedure

- (1) Compressive load shall be 25 to 100 psi, respectively.
- (2) Time span of test shall be 30 days and 6 months, respectively.
- (3) Test shall be conducted at $75 \pm 5^{\circ}\text{F}$, and $140 \pm 5^{\circ}\text{F}$, respectively.

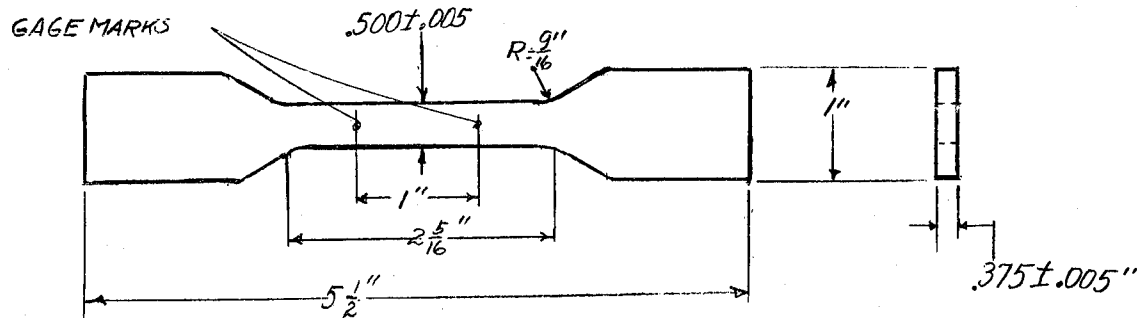
e. The report shall include

- (1) Age of specimen before test.
- (2) Time span of test.
- (3) Temperature control during test.
- (4) The original dimensions of the specimen, including the original thickness, t_0 .
- (5) The actual compressive load on the specimen.
- (6) The thickness of the specimen 30 minutes after removal of the load t_1 .
- (7) The compression set in inches, and expressed as a percentage of the original thickness, calculated as follows:

$$\begin{aligned}\text{Compression set (inches)} &= t_0 - t_1 \\ \% \text{ Compression set} &= \frac{t_0 - t_1}{t_0} \times 100\end{aligned}$$

RS-4 Tensile Strength and Elongationa. Specimen

- (1) Specimen shall be machined from the unbonded portion of the Gel time specimen, Test GS-2.

H. SPECIFIC SCREENING TESTS FOR RESILIENT RESIN SYSTEMS (Continued)RS-4 Tensile Strength and Elongation (Continued)a. Specimen (Continued)TENSILE TEST SPECIMEN

- (2) Two parallel gage lines 1" apart, for use in determining elongation, shall be marked on the reduced section of the specimen by means of a suitable instrument tape or crayon that will not scratch the specimen. The lines shall be perpendicular to the longitudinal axis of the specimen, one on each side of the center and 0.5 inch therefrom. The marks shall be as fine as possible, consistent with legibility, and shall not be deep enough to cause a weakening of the specimen.

b. Testing machine

Tensile strength and elongation shall be determined on a power-driven apparatus of either the beam-weighing or pendulum type conforming to the following requirements:

The applied tension as indicated by a dial or scale shall be accurate within 1 per cent.

The indicator shall remain at the point of maximum load after rupture of the test specimen.

The rate of travel by the power-actuated grip shall be 2 inches per minute and shall be uniform at all times. The machine shall be equipped with a scale or other device graduated to 0.1 inch for measuring elongation.

H. SPECIFIC SCREENING TESTS FOR RESILIENT RESIN SYSTEMS (Continued)RS-4 Tensile Strength and Elongation (Continued)b. Testing machine (Continued)

The testing machine used for a given test specimen shall be of such capacity that the maximum load required to break the specimen shall not exceed 85 per cent nor be less than 15 per cent of the rated capacity.

c. Grips

The grips which hold the specimen in the testing machine may be of a wedge type which tighten automatically and exert a uniform pressure across the gripping surface proportional to the applied tension, or of the type which may be tightened by screw pressure by hand. The gripping surfaces shall be knurled to prevent slippage of the test specimen.

d. Reporting results

- (1) Ultimate tensile strength, expressed in psi, shall be calculated by dividing the maximum load in pounds by the original area of cross-section of the test specimen in square inches and shall be expressed in psi.
- (2) Ultimate elongation shall be calculated by subtracting the original distance between gage marks in inches (1 inch) from the total distance between the marks at the time of rupture, and expressing this difference as a percentage of the original distance, as follows:

$$E = \frac{d - 1.0}{1.0} \times 100$$

where:

E= ultimate elongation in percent, and
d= distance between gage marks on the specimen at the time of rupture.

RS-5 Sensitivity to Casting Temperatures, 55 and 95°FNote:

Test shall be performed at two different environmental temperatures, 55 and 95°F respectively. Relative humidity shall be $50 \pm 20\%$. The fabrication and testing steps shall be identical with temperature as the only variable. For purposes of simplification, in this test method, the words "test temperature" shall mean either 55 or 95°F, whichever applies to the test being conducted.

H. SPECIFIC SCREENING TESTS FOR RESILIENT RESIN SYSTEMS (Continued)

RS-5 Sensitivity to Casting Temperatures, 55 and 95°F (Continued)

- a. One-half inch thick Kirksite sheets shall be coated with a suitable parting agent. The dimensions and damming of the sheet shall be such as to result in a $3/8 \pm 1/32$ " thick x 6" x 6" specimen. The plastic shall be in contact with Kirksite at all surfaces except one edge open for pouring.
- b. Materials and mold shall be stabilized at the test temperature.
- c. A mix totaling eight fluid ounces shall be prepared in a one pint metal container in accordance with E.2. above and immediately cast into the mold.
- d. The casting shall be allowed to cure at the test temperature for six hours. The casting shall then be removed from this environment and allowed to cure at $75 \pm 5^\circ\text{F}$.
- e. Hardness change during the curing period shall be determined as in Test RS-1 above.
- f. A curve with hardness change vs. time as coordinates shall be plotted and reported.

J. CONTROL TESTS-DETERMINING BATCH TO BATCH CONSISTENCY, RIGID AND RESILIENT RESINS

I. Working Properties

C-1 Viscosity of each component

- a. All materials shall be stabilized at $75 \pm 0.5^\circ\text{F}$. immediately prior to test. Ambient room temperature shall be $75 \pm 5^\circ\text{F}$.
- b. A Brookfield viscometer, equipped with a calibration sleeve over the guard arms, shall be used to determine viscosity (in cps.) of each component in the resin system.

C-2 Gel time on Kirksite

- a. An one-half inch thick Kirksite sheet shall be coated with a suitable parting agent. The dimensions and damming of the sheet shall be such as to result in a $3/8 \pm 1/32$ " x 6" x 6" plastic casting.
- b. The components of the resin system shall be mixed in accordance with E.2. above. The total volume shall be 30 ± 2 fluid ounces in a one quart metal container.
- c. 7.5 fluid ounces shall be cast onto the Kirksite sheet. The top surface of the casting shall be exposed to the ambient air.

J. CONTROL TESTS-DETERMINING BATCH TO BATCH CONSISTENCY, RIGID AND RESILIENT RESINS (Cont'd)1. Working Properties (Continued)C-2 Gel time on Kirksite (Continued)

- d. Gel time shall be considered as that time period from the zero point to the time at which the blended resin is no longer fluid to the moderate scooping action of a tongue depressor or other suitable instrument.

C-3 Pot life, 3" thick mass in 1 quart metal container

- a. The remaining 22.5 fluid ounces shall be used for the pot life determination. Pot life shall be considered as that time period from the zero point to the time at which the blended resin is no longer fluid to the moderate scooping action of a tongue depressor or other suitable instrument.

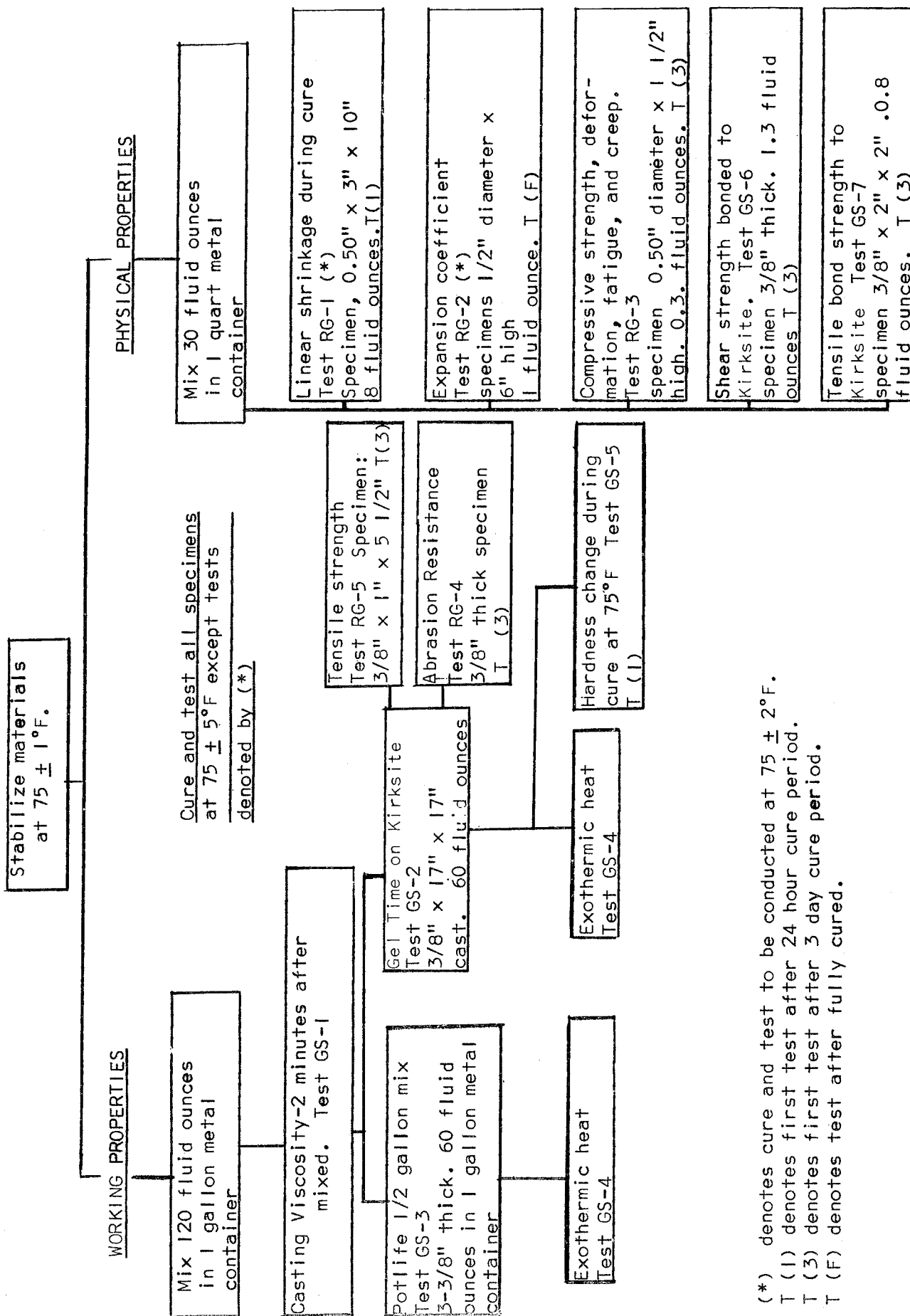
2. Chemical TestsCH-1 Forming Oil Resistance

- a. Specimen shall be 3" x 3" unbonded portion of the Gel time specimen, Test GS-2. Edges of specimen shall be smooth, but not rounded or beveled. Specimen shall have aged for 48 hours immediately prior to test.
- b. Shore hardness shall be determined in accordance with E.1. above.
- c. Specimen shall be weighed on a suitable analytical balance to within .005 grams.
- d. Specimen shall be completely immersed in the lubricant for 24 hours.
- e. Specimen shall be removed from the lubricant and wiped dry with a clean dry cloth.
- f. Specimen shall be weighed to within .005 grams.
- g. Shore hardness shall be determined in accordance with E.1. above.
- h. Weight increase and hardness change shall be reported as well as any other deleterious changes.

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SCREENING TESTS - RIGID CASTING RESIN SYSTEMS (TOOLING)

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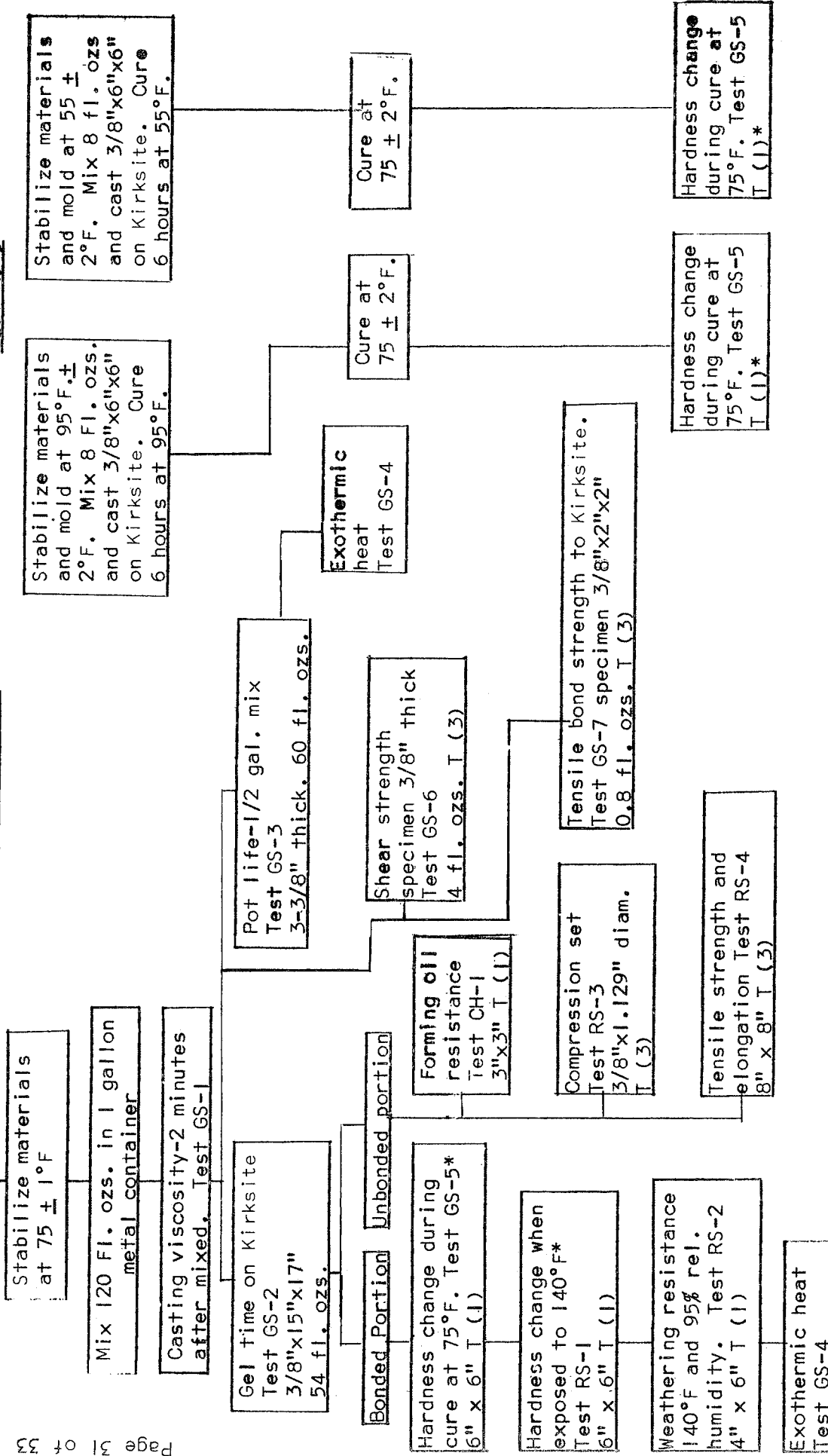
(*) denotes cure and test to be conducted at 75 ± 2°F.
 T (1) denotes first test after 24 hour cure period.
 T (3) denotes first test after 3 day cure period.
 T (F) denotes test after fully cured.

SCREENING TESTS-RESILIENT CASTING RESIN SYSTEMS (TOOLING)

WORKING PROPERTIES AND PHYSICAL PROPERTIES

Cure and test all specimens at $75 \pm 5^\circ\text{F}$, except test denoted by (*)

SENSITIVITY TO CASTING TEMPERATURES
TEST RS-5

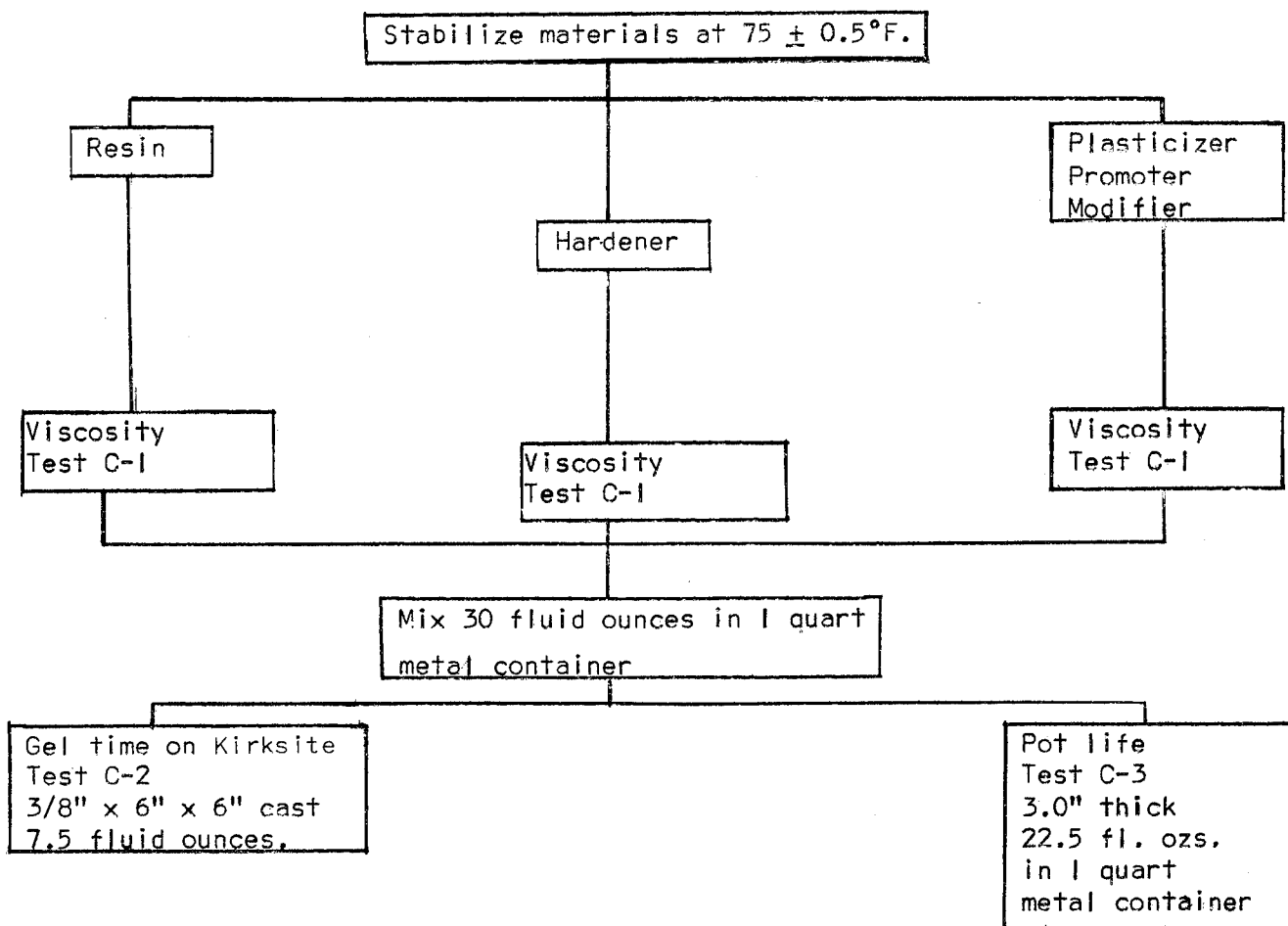


* denotes cure and test at $75 \pm 2^\circ\text{F}$.

T (1) denotes first test to be conducted after 24 hour cure period.

T (3) denotes first test to be conducted after 3 day cure period.

CONTROL TESTS RIGID AND RESILIENT CASTING RESIN SYSTEMS (TOOLING)
BATCH TO BATCH CONSISTENCY



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CHECKED BY _____
DATE 12-13-56
TITLE _____

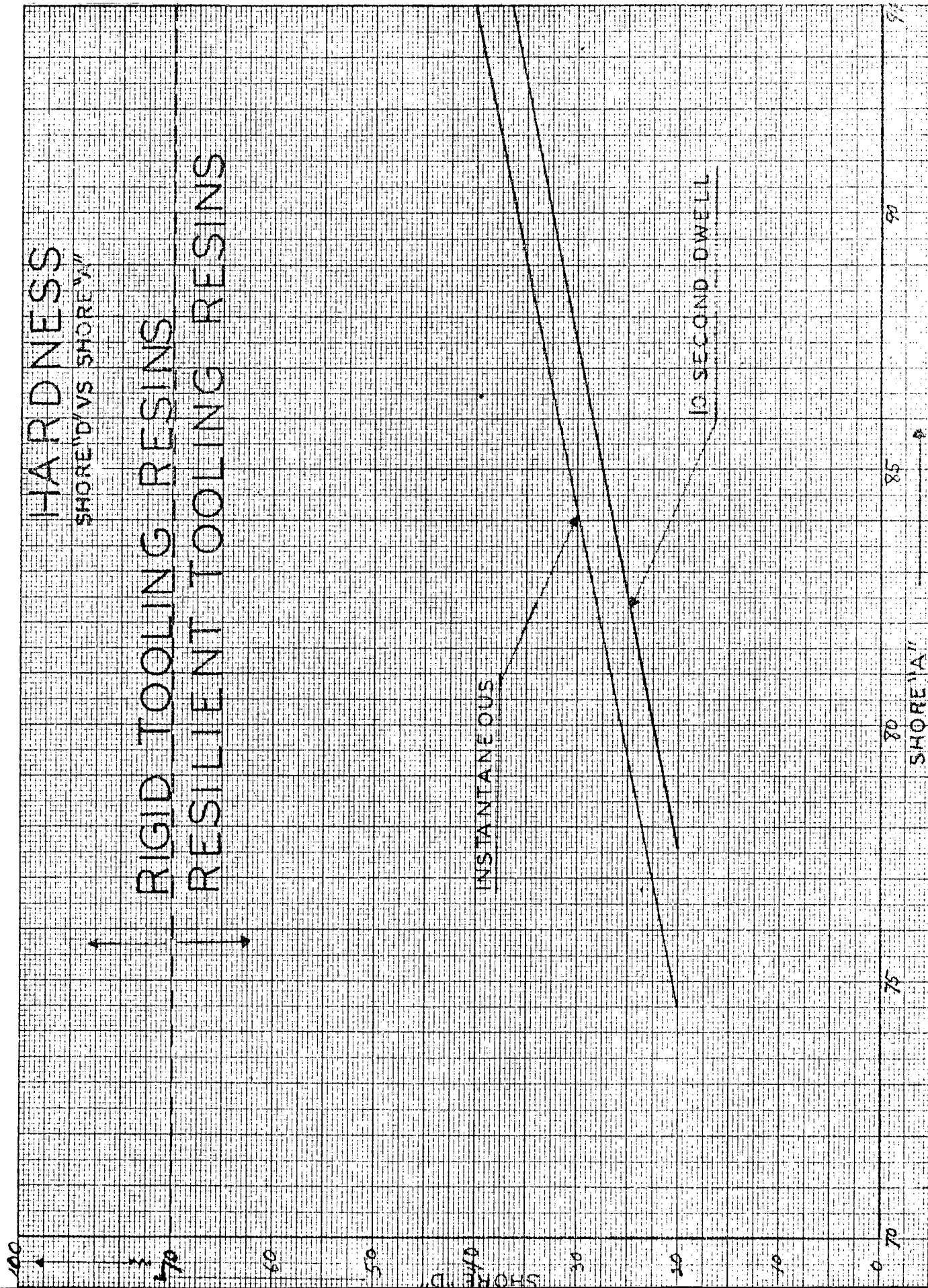
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